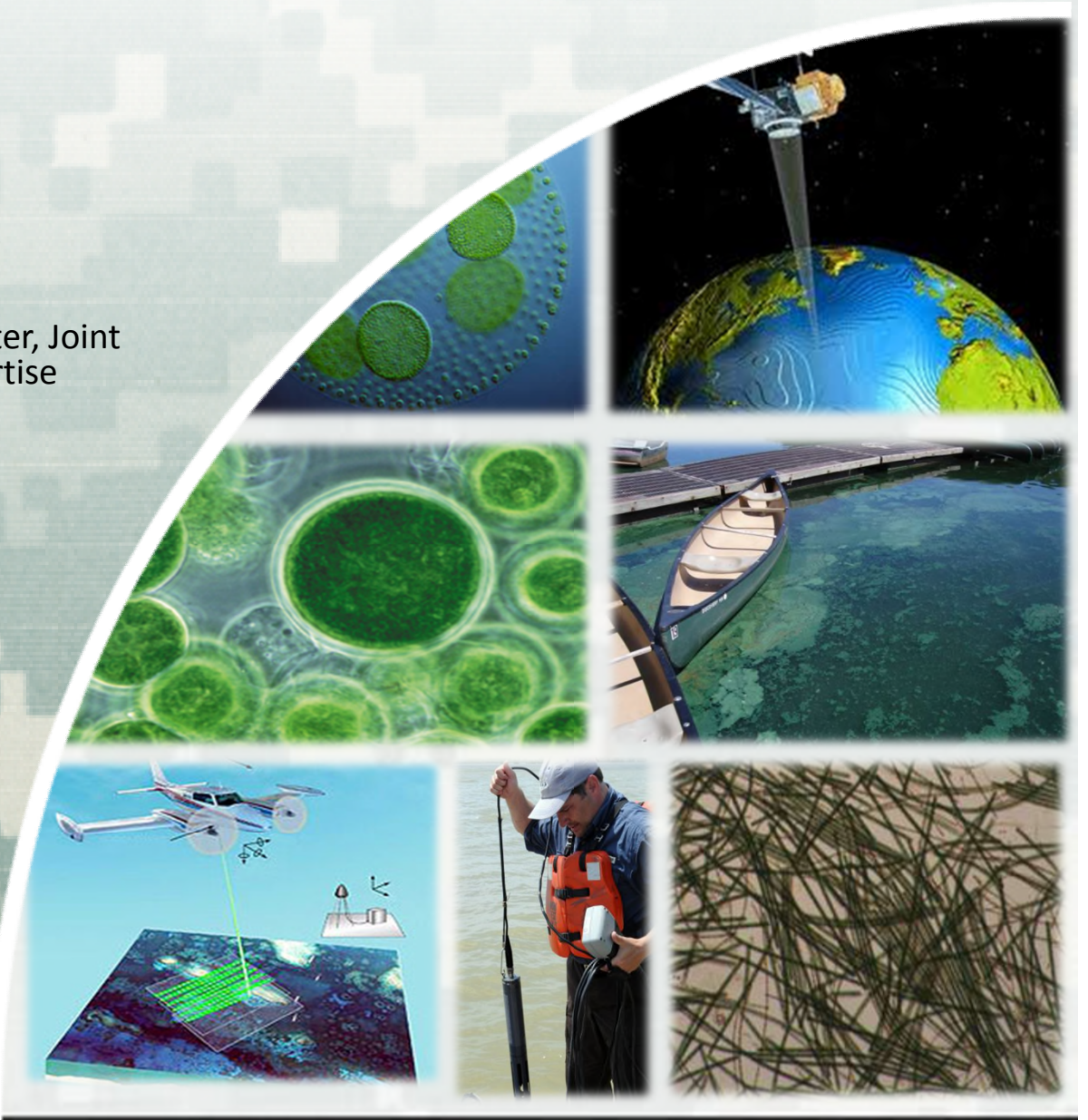
Harmful Algae Blooms (HAB): A U.S. Army Corps of Engineers Perspective

Gerard A. Clyde, Jr., Ph.D – Tulsa District
Erich B. Emery – Lakes and River Division, Ohio River
Kathryn L. Tackley – Portland District
Molly Reif – Engineer Research & Development Center, Joint Airborne Lidar Bathymetry Technical Center of Expertise

National Water Monitoring Conference
Tampa, FL May 2-6, 2016



US Army Corps of Engineers
BUILDING STRONG®

U.S. Army Corps of Engineers

Mission: Provide vital public engineering services in peace and war to strengthen our Nation's security, energize the economy, and reduce risks from disasters.

- 9 Divisions
  - Support to over 100 countries
- 43 Districts across the U.S., Europe, and Asia

http://www.swf.usace.army.mil/Locations.aspx

USACE Stats (FY13)

from Value to the Nation: http://www.corpsresults.us/watersupply/wsfastfacts.cfm

- 420 lakes in 43 states
  - hosting 33% of all fresh water fishing
  - 4,628 recreation areas
    - 80% within 50 miles of a large U.S. city
- 7,829,605 acres of land and 5,630,584 acres of water under USACE management (~ 2% of all federal lands)
  - Hosting 20% of visits on federal lands
  - 56,000 miles of shoreline; 90,773 campsites; 2,022 playground sites; 959 designated swimming areas; 9,504 miles of hiking trail; 3,671 boat ramps; 110,735 marina slips
- 335,293,332 total visits (person-trips) in FY 2012
- 9,779,584 acre-feet of water supply
  - 9,359,419 currently under contract (95.7%)
  - 7,907.53 mgd yield currently under contract

Regional and National

USACE HAB IMPACTS

Historic USACE HAB Activities

Table 3. HAB occurrence and impact summary table.

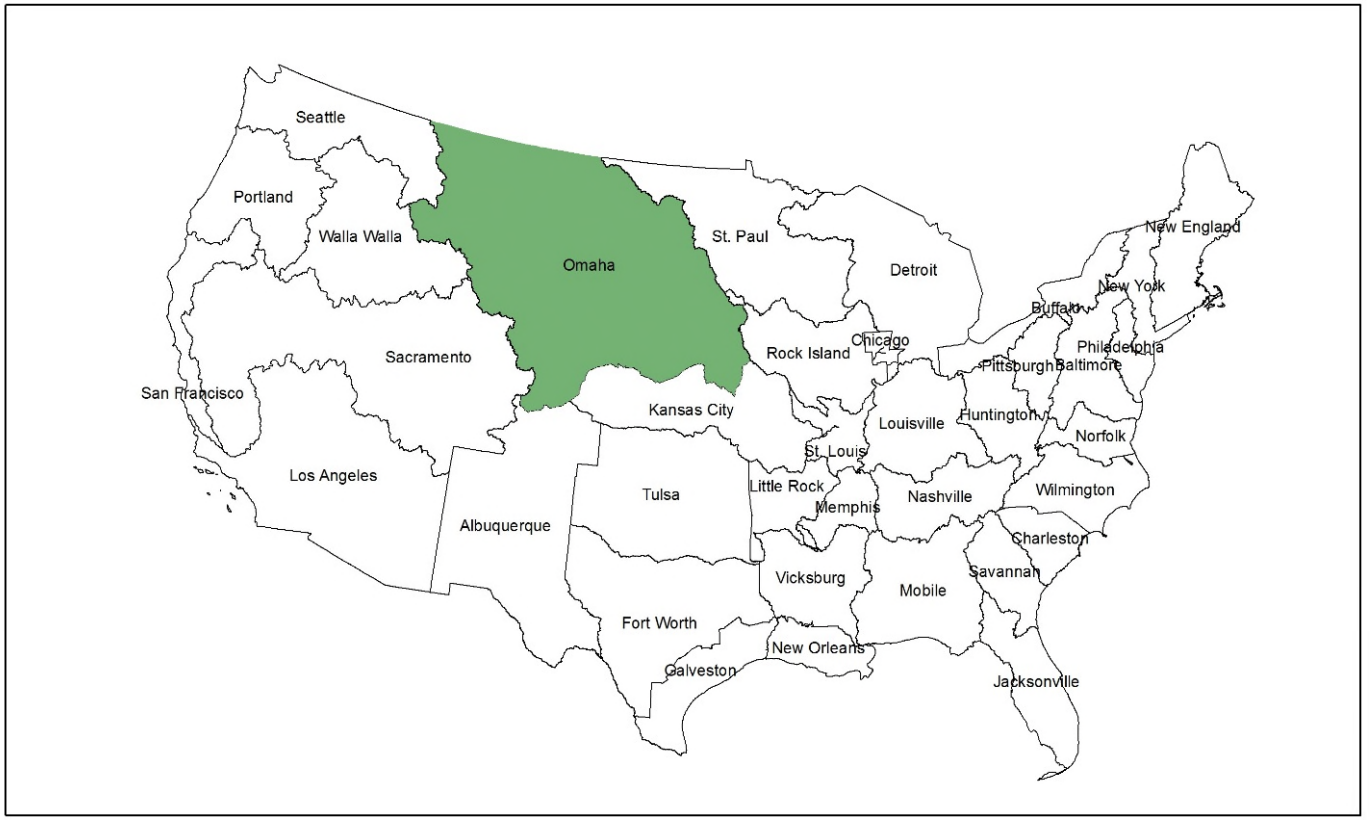
District	HAB Occurrence	HAB Impact
Louisville	Blooms occur at multiple Corps projects every summer, late in the season. Blue-green algae blooms have become a larger issue in the Louisville District in the past three years, most often in Indiana lakes, but also in Ohio and Kentucky bodies of water. Associated factors are thought to include eutrophication, oxygen depletion, high temperatures, and drought conditions.	Multiple projects have reported fish kills. Anecdotal reports of dogs that died after jumping into/drinking water high in algal toxins. Blooms have necessitated an increase in filtration and application of carbon to remove taste and toxins in the water supply. Beaches have been closed down due to blooms, and some people have reported skin rashes.
Norfolk	Large bloom occurred at the Craney Island Dredged Material Management Area in the summer of 2005.	Algal toxin effects are negligible, as the toxins dissipate in the wide mixing area of Norfolk Harbor and recreational activities do not take place in the region.
Buffalo	The Buffalo District manages and maintains many harbors along the south shore of Lake Erie, which currently faces multiple problems and concerns with algal blooms. Blooms have occurred on Lake Erie every summer, with a peak of 2-3 weeks, for at least the past 5 years.	No documented human health impacts have resulted thus far. Beaches have been closed as a precautionary measure.
Portland	Most of the Portland District projects have experienced algal blooms at one time or another. Blooms begin in June and last through the summer. In 2005, large blooms occurred at three of the 17 district projects; typically up to two-thirds of the district's projects experience a large bloom in a given year.	Despite bloom prevalence, health and property impacts were not specified.
Jacksonville	Blooms occurred at several of the district's biggest projects in 2005. Blooms seem to be associated with heavy rainfall periods.	Anecdotal reports of dead manatees. Many human health concerns, especially relating to potable water. Concerns will likely impact the design of a costly project where a downstream water quality treatment installation could increase costs.
Tulsa	Blooms occurred at six of the district's 36 projects in 2005. Marion Reservoir in Kansas blooms annually.	A dog is thought to have gotten sick from Microcystin at Marion Reservoir, Kansas. A golden algae bloom at Lake Texoma in January 2004 killed 25-30,000 fish. Golden algae threaten the striped bass fishery on the lake, which is a $40 million/year economic asset as reported by Paul Mauk, Oklahoma Department of Wildlife Conservation.

Table 5. HAB monitoring summary table.

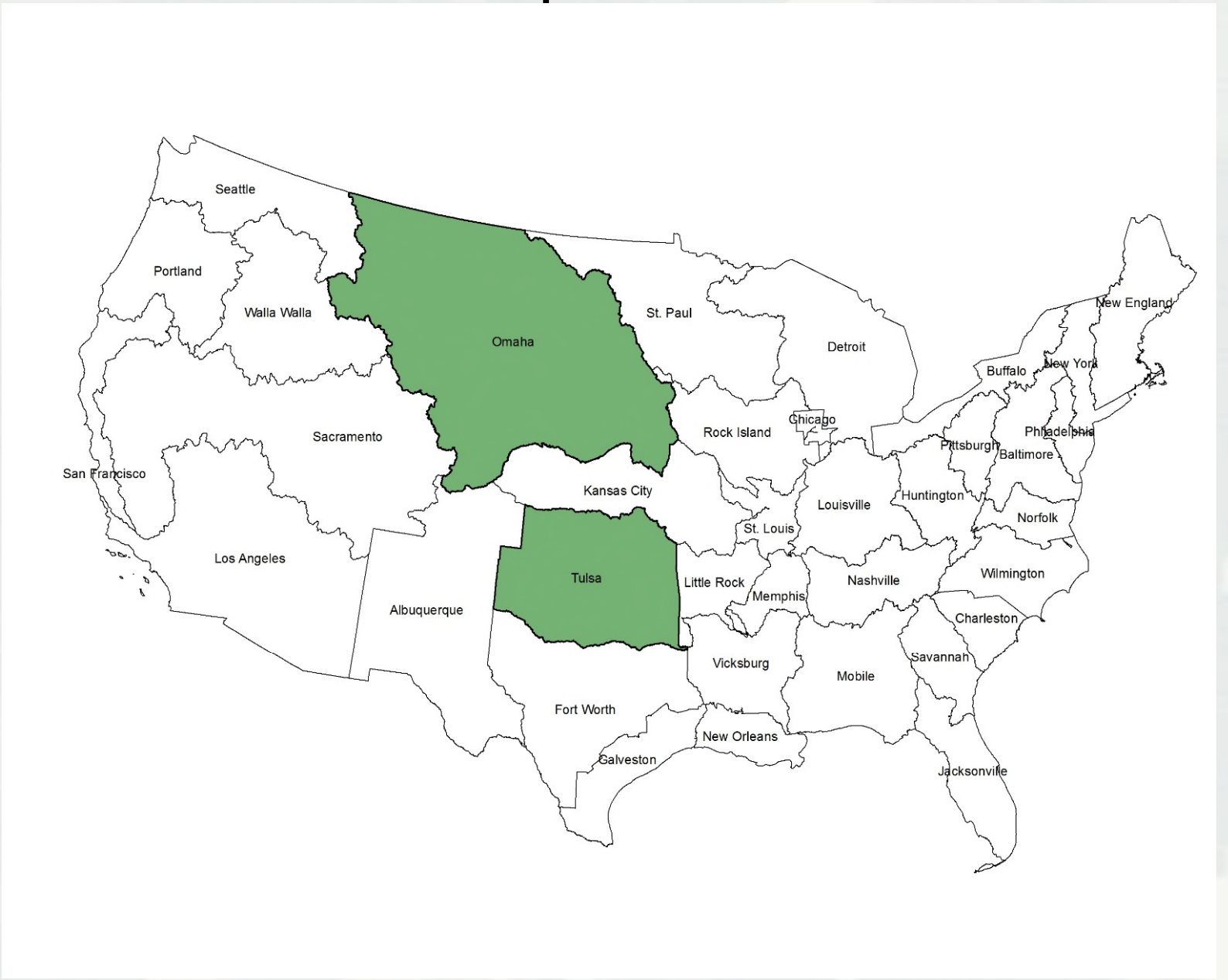
District	HAB Monitoring
Louisville	The Louisville District collects data from each of their reservoir projects, from the inflows and from the tail waters. At Harsha Lake the District conducted a modeling study, collecting data on a weekly basis through the summer of 2005. Sampling included five locations within the lake every four weeks at different depths. Measurements included metals, nutrients, phytoplankton, chlorophyll, and physical parameters. However, the budget only contains enough money to monitor other locations once a year (in August or September). The Corps collects water for analysis from different depths at tail waters, dam sites, and major tributaries. Special circumstances may warrant a closer look at other places. Other agencies, such as the Division of Water, Fish & Wildlife, and USGS, also collect data in Kentucky, as well as many Indiana agencies.
Norfolk	The Norfolk District has recently measured chlorophyll A levels at Craney Island. USACE noticed these levels increasing over the summer of 2005. Levels started fairly low (i.e. levels the previous winter were around 1-2 ug/L, but levels in the spring and summer were 15-20 ug/L). USACE does not have past summer background measurements and has not done testing until the last few years.
Buffalo	The Buffalo District does not collect data related to algal blooms.
Portland	For the past ten years, the Portland District has taken comprehensive measurements at three projects: the Willow Creek Reservoir (which often experiences algal blooms), Lost Creek Lake, and Applegate Dam. Sample analysis consists of organism ID, cell counts, cell density, and biovolume, as well as environmental factors (including temperature, pH, turbidity, dissolved oxygen, dissolved solids, etc.). Samples are generally 500 mL to 1 L, taken from the top layer of water. Due to budget constraints, samples are not taken regularly at other projects and often include analysis for fewer factors. The interviewee estimated that monitoring all projects on a weekly basis would take over $100,000 per year, which is much larger than the District's entire water quality budget.
Jacksonville	Rather than USACE, the Florida DEP and South Florida Water Management District often sample for algal blooms. The Jacksonville District has, however, collected data about cyanobacteria at sites connected with the Aquifer Storage & Recovery Project. These data are taken from four sites (Lake Okeechobee, Kissimmee River, Hillsboro Canal, Caloosahatchee River), quarterly for one year. Sampling is expensive.
Tulsa	In 2005, the Tulsa District took measurements at the Marion and Fort Gibson reservoirs. Microcystin levels ranged from 2.9 to 9.6 ppb at Marion (June 8th to July 13th, samples taken every two weeks, possibly 60 or 70 samples); 2.8 to 3.6 ppb at Fort Gibson (July 6th, possibly 40 samples). Samples were also taken at Tenkiller Reservoir in 2005, and Skiatook Lake samples were taken on a day at peak of cylindrospermopsin bloom near a swim beach. All told, approximately 360 samples were taken during the year. Data include nutrient levels, total phosphorous, nitrate/nitrite, ammonia, organic carbon, chloride, and total calcium in some lakes, as well as vertical profiles of turbidity, oxygen, pH, conductivity, temperature, chlorophyll, and some light data. Most samples are surface samples; others are a half meter below surface or a meter above the bottom, taken in 1-L amber bottles, split between microcystin and cylindrospermopsin analysis. Historically, the District has had chlorophyll data, but now Dr. Bob Lynch at OU is doing phytoplankton analysis for them.

Excerpted from ERDC/TN ANSRP09-1, The Impact of Harmful Algae Blooms on USACE Operations: http://el.erdc.usace.army.mil/elpubs/pdf/ansrp09-1.pdf

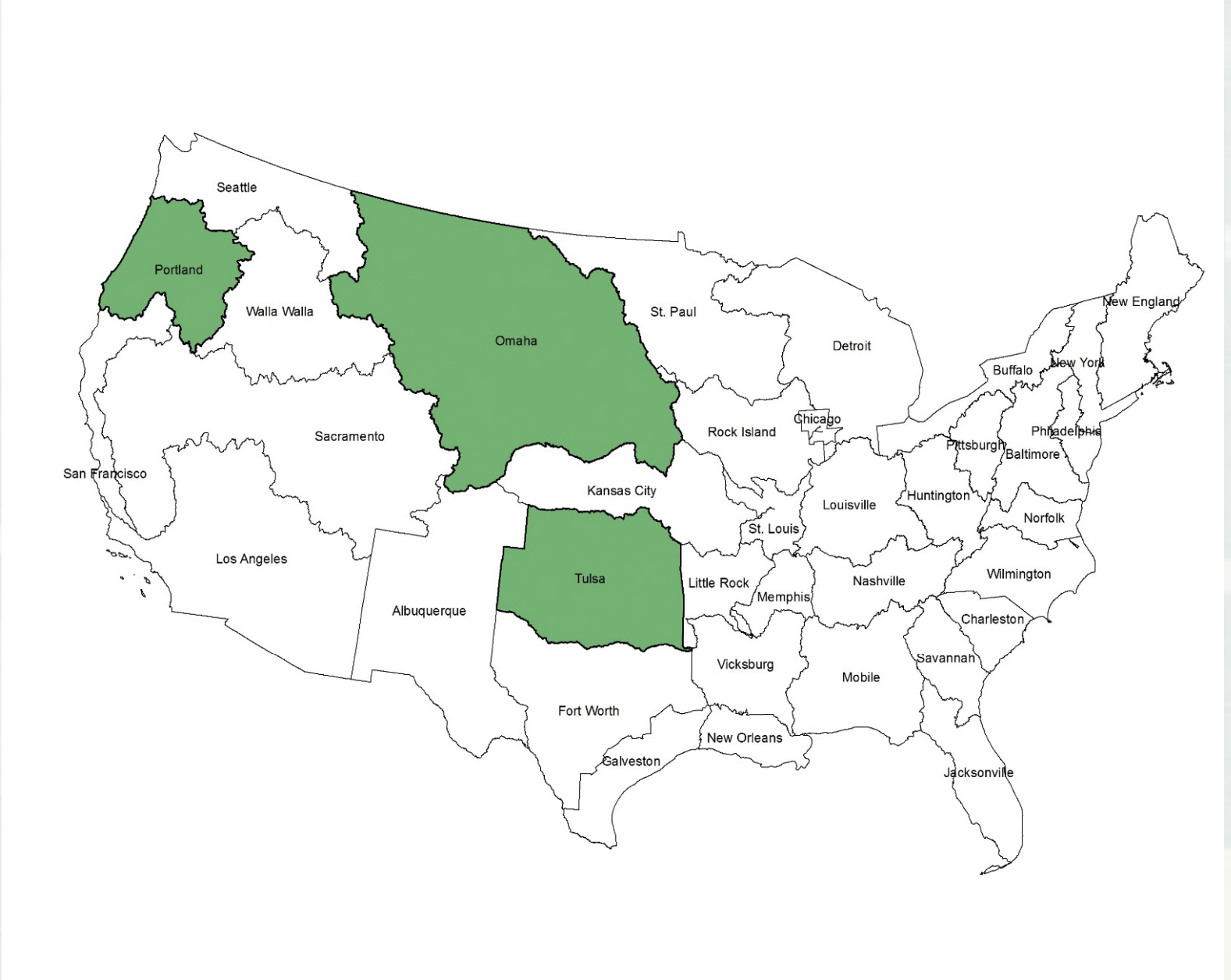
USACE Districts Regularly Reporting HAB Events and Impacts - 2004



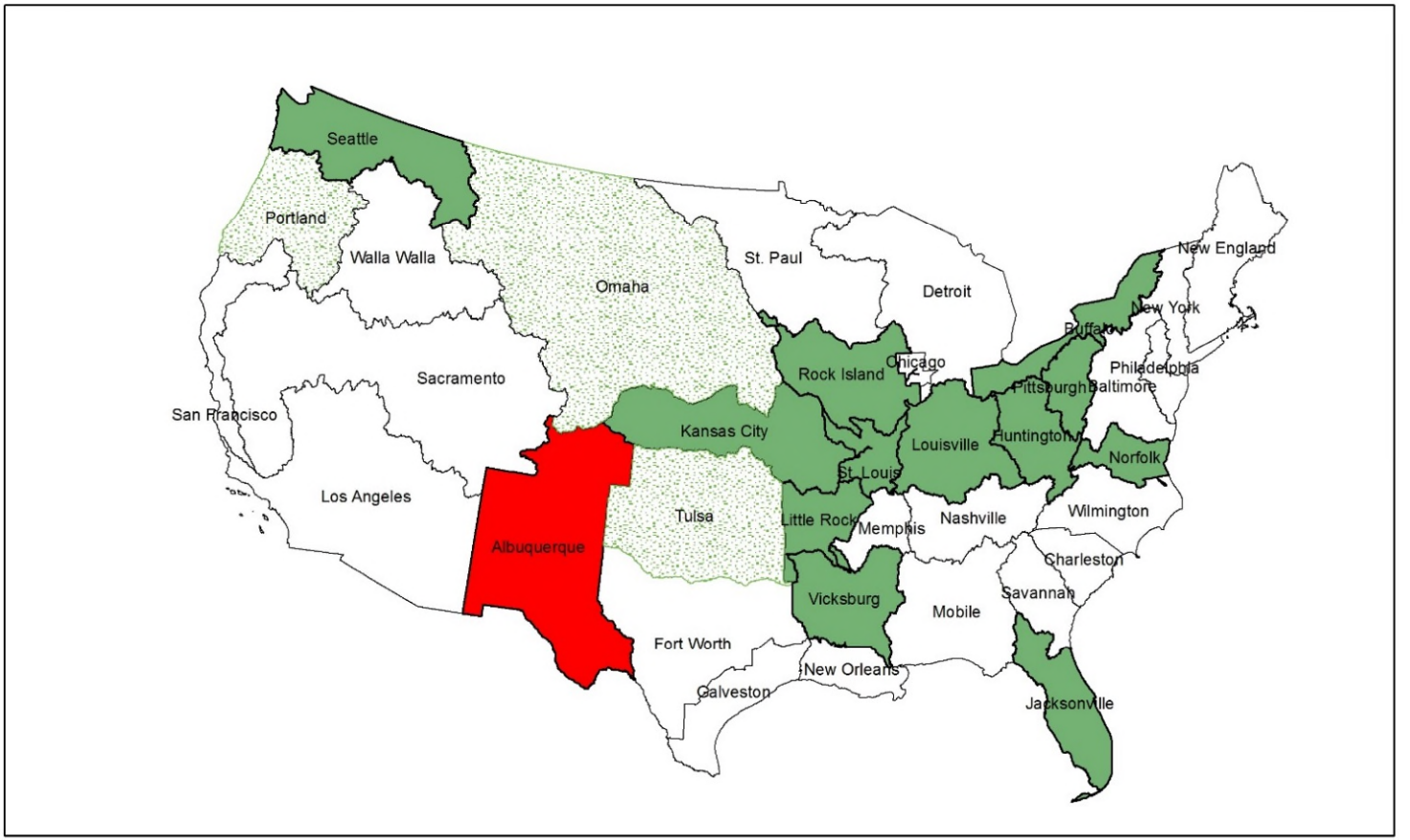
USACE Districts Regularly Reporting HAB Events and Impacts - 2007



USACE Districts Regularly Reporting HAB Events and Impacts - 2009



USACE Districts Regularly Reporting HAB Events and Impacts - 2012



Summary of National Impacts (FY15)

District	Do you have a District HAB response plan/protocol?	HAB Algal Group	Percent of Project experiencing HABs	Area of Impact
Kansas City	No[1]	Cyanobacteria Dinoflagelates	10	Entire lake, coves open water
Rock Island	Yes	Cyanobacteria		Coves, open water
Huntington	Yes[1]	Cyanobacteria	5	Coves, open water
Pittsburg	Yes[1]	Cyanobacteria Prymnesiophyta	15	Limited to coves only Entire lake, open water
Louisville	Yes[1]	Cyanobacteria	60	Entire lake
Omaha	No[1]	Cyanobacteria	5	Entire lake
Jacksonville	Yes[1]	Cyanobacteria	< 10	No Response
Vicksburg	No[1]	Cyanobacteria		No Response
Seattle	No[1]	Cyanobacteria	1	Coves, open water
Portland	Yes[1]	Cyanobacteria	25	Entire lake, coves, open water
St. Louis	No	Cyanobacteria	< 5	Coves, open water
Tulsa	Yes[1]	Cyanobacteria Prymnesiophyta	40	Limited to coves only Entire lake, open water

Summary of National Impacts (FY15)

- Across USACE:
  - HAB frequency is increasing (Observations > 5 years = stable)
  - HAB intensity is increasing (Observations > 5 years = stable)
  - HAB duration is increasing stable/increasing (Observations > 5 years = increasing)
  - HAB magnitude is stable/increasing (Observations > 5 years = stable/decreasing)
  - HAB persistence is stable/increasing (Observations > 5 years = increasing)
  - Most observations only in last 2-5 years
- Impacts have included:
  - Human illness
  - Pet illness/death
  - Wildlife deaths
  - Reduced visitation
  - Negative press reports
- Majority of District HAB protocols developed since 2011
  - Omaha – 2003
  - Tulsa – 2004
  - Portland - 2007

Impacts from HABs Experienced by USACE

- Lake closures
  - Impacts to economy
  - Frustrated public/business owners
- Increased workload and cost to monitor HABs
  - Challenges in scaling lake monitoring to ensure public safety
  - Has resulted in limiting resources for other public outreach (Corps' life jacket campaign, campground maintenance, etc)
- Public education challenges/effectiveness
  - Mitigated somewhat by state HAB programs, varies state to state
  - monitoring and public notification practices differ from state to state – this is confusing!
  - Need for national perspective and national guidance
- Human and dog illnesses

Financial Impacts: Grand Lake

Print this page

TULSA WORLD

Powered by the largest news staff in Northeastern Oklahoma

Visit tulsaworld.com for coverage of news, business, sports and entertainment.

Return to Story

Sales tax numbers show algae had little effect on Grand Lake revenue

by: RHETT MORGAN World Staff Writer
Monday, August 29, 2011
8/29/2011 7:34:46 AM

KETCHUM - Municipal sales tax numbers that coincide with Gran
difference in lake town revenues compared to the same period a y

Noting the algae outbreak, the Grand River Dam Authority on July
chilling those who typically flock there over the Fourth of July weel

With the main part of the lake testing negative for the toxins, the G

The city of Grove's sales tax deposit letter for August, which reflec
$554,364, roughly a 6 percent increase over the same period in 2

Other lake cities showed negligible change as well. The town of La
same month a year ago, and the city of Ketchum dipped slightly, C
Bernice and Disney, however, rose slightly.

Tulsa World: August 29, 2011

Sales tax revenues at selected Grand Lake towns

Key: 2010 2011

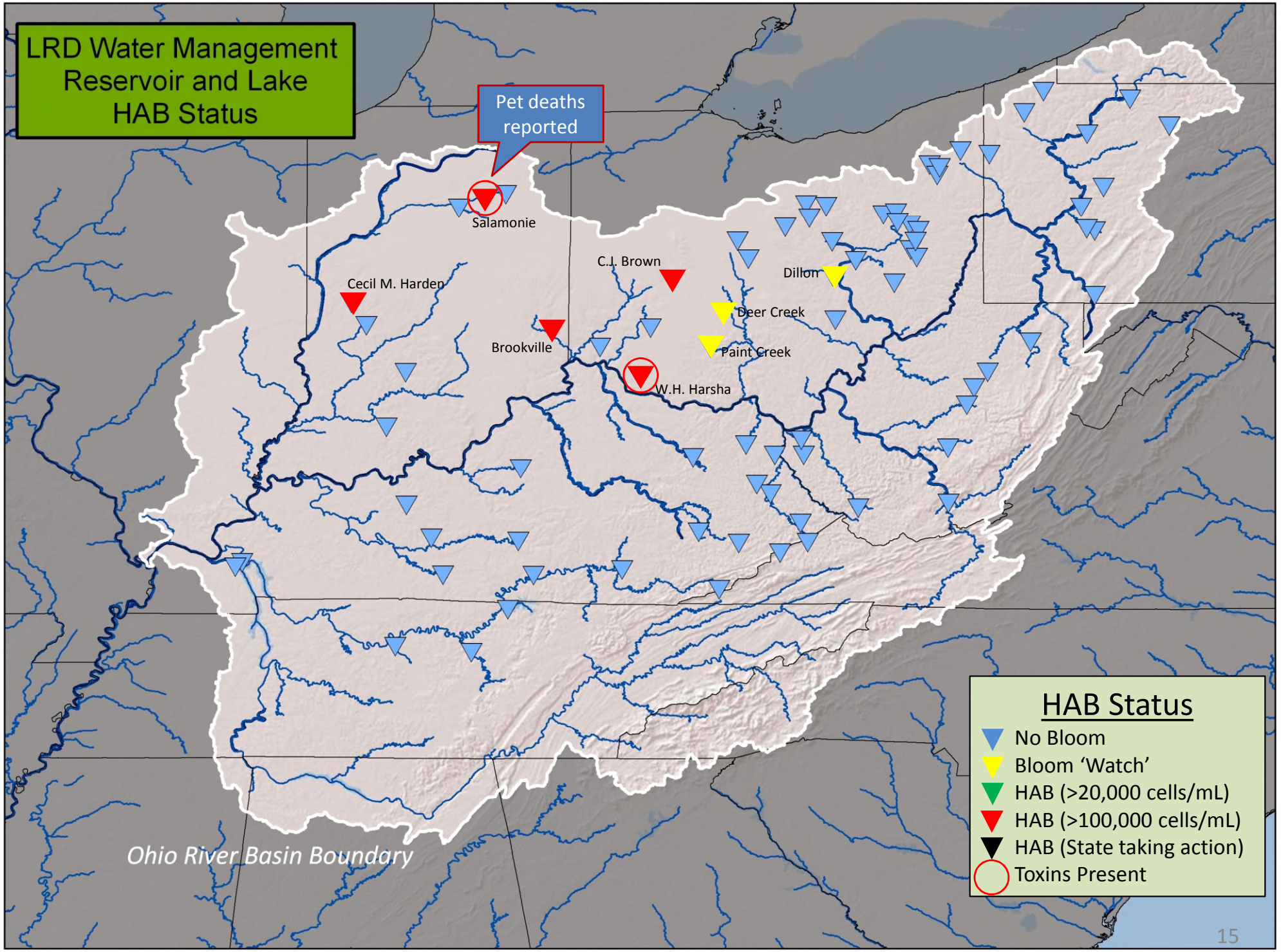
Grand Lake Towns	July*		August**	
Grove	$515,075	$516,462	$523,754	$554,364
Disney	$6,702	$6,297	$5,806	$5,932
Langley	$81,026	$79,842	$79,581	$77,439
Ketchum	$11,291	$17,005	$20,510	$19,928
Bernice	$17,077	$17,605	$16,734	$17,731

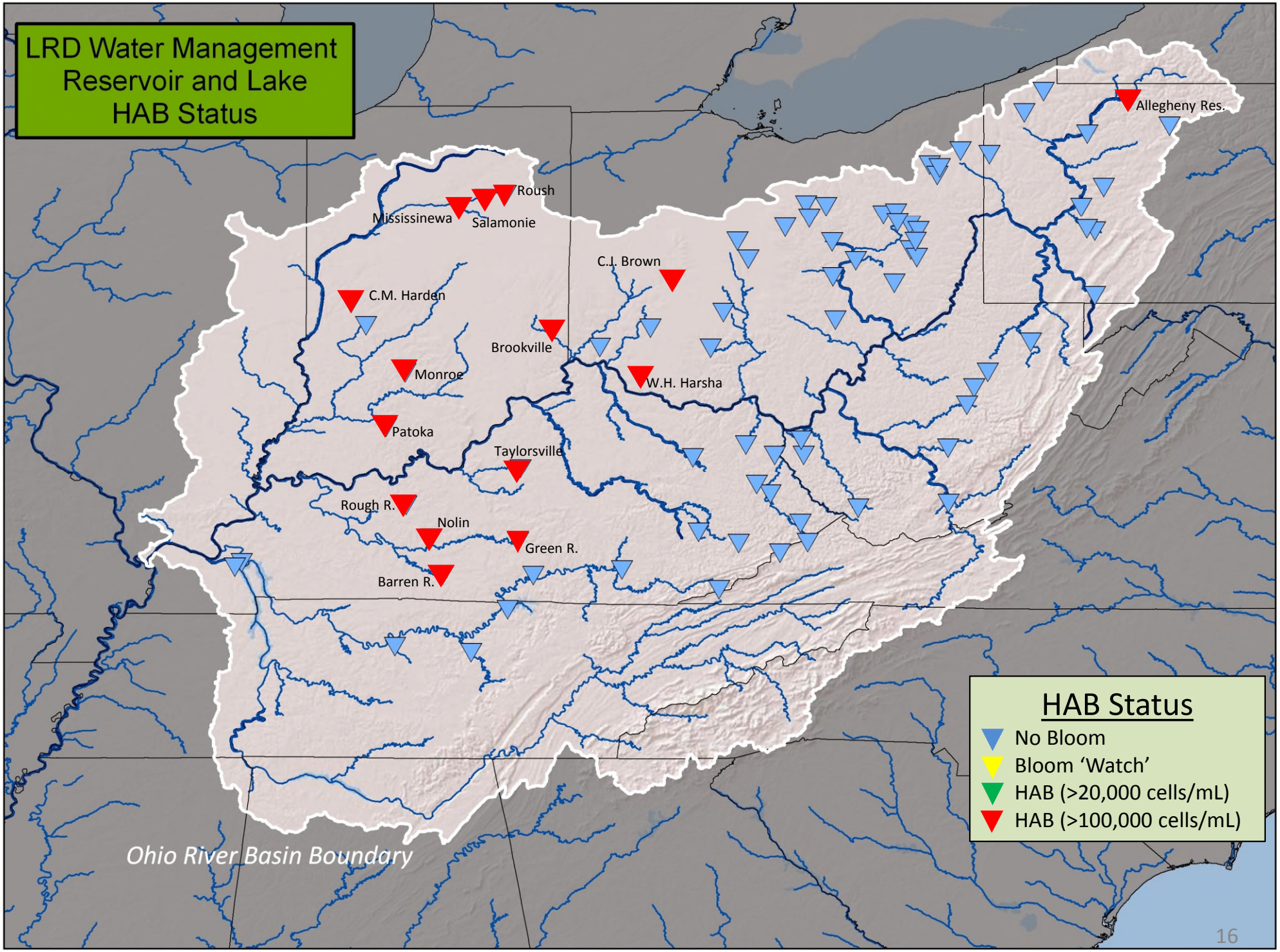
*Reflects collections from May 16 to June 15

** Reflects collections from June 16 to July 15

Note:
1. Not adjusted for changes in sales tax rate.
2. Representative of July/August only.
3. Indicates the need to better understand the economic impact of HABs on a site specific, local, and regional scale.

Regional Impacts from HABs
Ohio River Basin

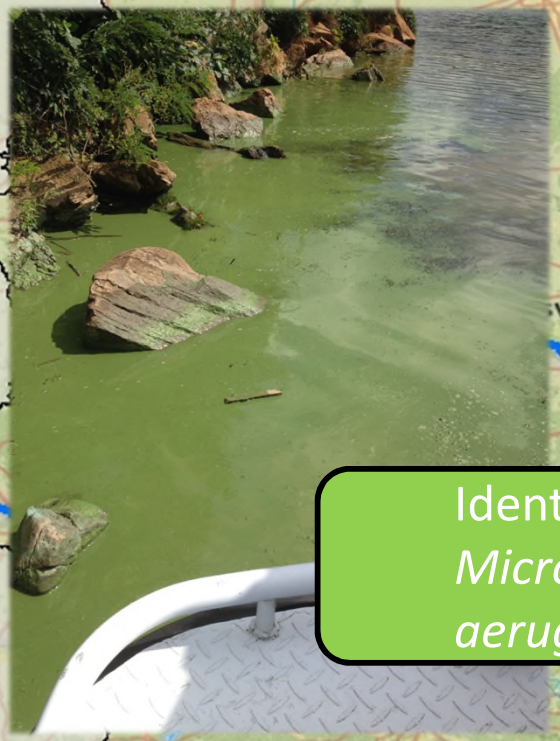

LRD Water Management Reservoir and Lake HAB Status
Pet deaths reported
Salamonie
Cecil M. Harden
C.J. Brown
Dillon
Deer Creek
Brookville
Paint Creek
W.H. Harsha
Ohio River Basin Boundary
HAB Status
No Bloom
Bloom 'Watch'
HAB (>20,000 cells/mL)
HAB (>100,000 cells/mL)
HAB (State taking action)
Toxins Present


LRD Water Management Reservoir and Lake HAB Status
Allegheny Res.
Roush
Mississinewa
Salamonie
C.J. Brown
C.M. Harden
Brookville
Monroe
W.H. Harsha
Patoka
Taylorsville
Rough R.
Nolin
Green R.
Barren R.
Ohio River Basin Boundary
HAB Status
No Bloom
Bloom 'Watch'
HAB (>20,000 cells/mL)
HAB (>100,000 cells/mL)

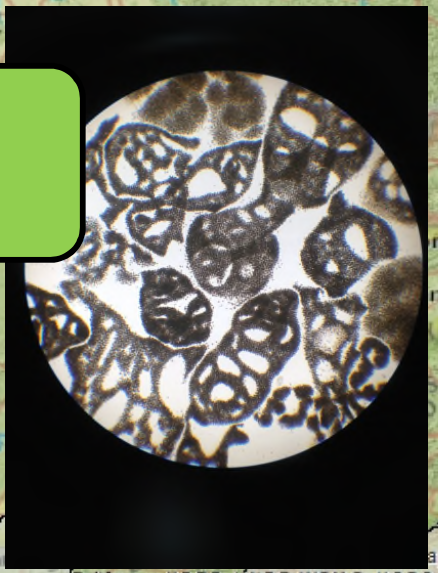
AUG | SEP | OCT

19-AUG

Reported ‘paint spill’ at ORM 84



Identified as *Microcystis aerugenosa*



Toxin concentration 41 ug/L

USACE Airborne Survey

- Orthoimagery - high-resolution, 4-band aerial images
- ADS80, with RGB/IR at 53cm resolution; 30 degree window
- 18+ hrs flying time

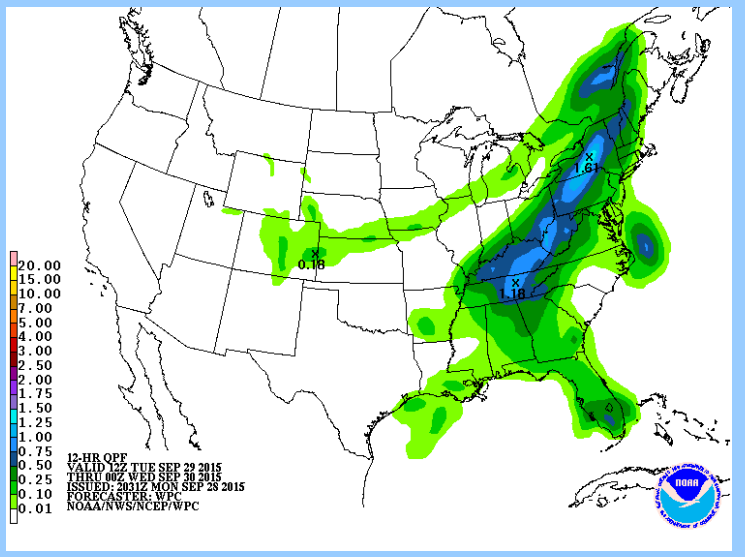
- Images were available within 36 to 48 hours
- The imagery is available on SmartView Connect
  - http://maps.woolpert.com
  - Username: jalbtcx
  - Password: Airborne2015

AUG | SEP | OCT

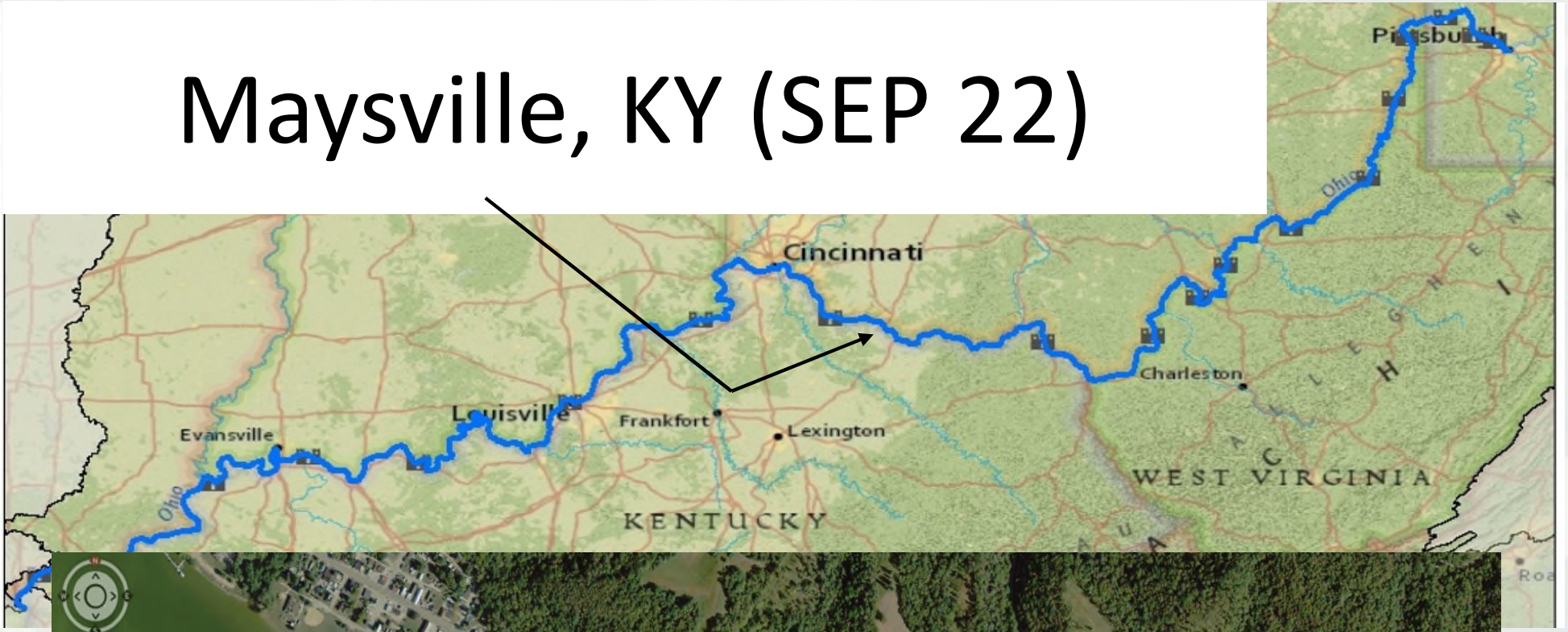
Week of 28-SEP

Report of localized algae near Evansville Water (ORM 791).

30-SEP RAIN!!!



Maysville, KY (SEP 22)

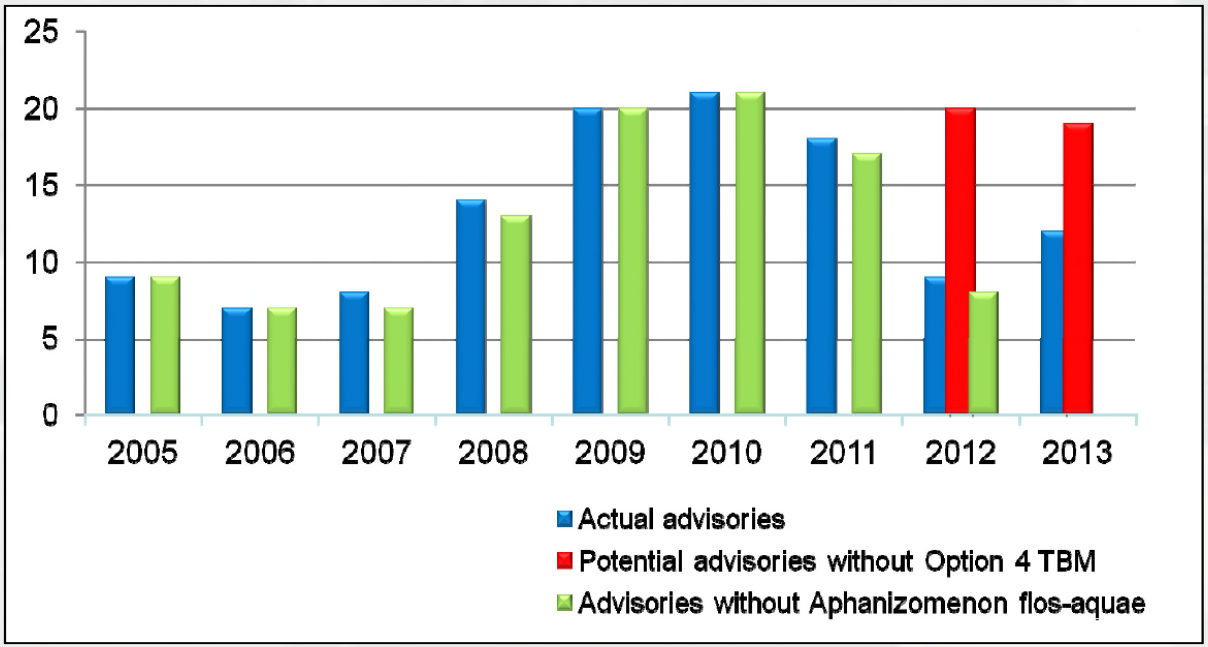


Maysville, KY

AGENCY COLLABORATION

State Agency Collaboration in Oregon

- The State of Oregon Health Authority (OHA) suggests monitoring Oregon lakes with heavy recreational use.
  - Participation in lake monitoring, however, varies across the state.
- Lake monitoring in Oregon has changed over time.
- In 2012, most Oregon lake managers moved to toxin-based monitoring (developed by OHA) to avoid "unnecessary" lake closures.
  - Based on the fact that *A. flos-aquae* has not been known to produce toxins in Oregon
  - This has reduced the number of lake closures and negative impacts to local economies
  - Toxin-based monitoring is supported by the OHA and is one of four recommended options for lake monitoring



(data courtesy of Oregon Health Authority)

Current Corps' Portland District Management of HABs

- The Corps of Engineers Portland District's management of HABs has changed in recent years as well.
  - Instead of "chasing blooms" the Portland District now focuses primarily on public outreach and education (reservoirs are posted year-round).
  - Portland District no longer monitors for HABs on a regular basis.
  - These policy changes prevent public reliance on lake postings/closures and a false sense of security.
- Satellite monitoring of HABs continues by Corps' water quality staff.
  - If large bloom is found through satellite monitoring, sampling/testing is conducted as necessary; information is shared with State Oregon Health Authority and Corps' Public Affairs Office.
- Some district partners continue to monitor for HABs on Corps reservoirs (ex: U.S. Forest Service campgrounds on Corps' Reservoirs).
  - Can be confusing to public.
  - Public outreach & education critical!

State Agency Coordination – Tulsa District

- In 2004, Tulsa District adopted the WHO guidelines
- Between 2004 and 2011 Advisories and/or Warnings only issued at Marion and R.S. Kerr Reservoirs (based on WHO guidelines)
- In 2011 the Tulsa District incorporated the cyanoHAB response and reporting protocols in its Kansas AOR to those adopted at by the KDHE (2003 WHO guideline)
- In 2012 the Tulsa District discontinued use of the WHO guidelines in its Oklahoma and Texas AOR.
  - Implemented provisions of SB 259 signed into law on May 22, 2012 at OK lakes as well as Texas side of Texoma and Pat Mayes lake in Texas
  - Continue to follow KDHE cyanoHAB policy in KS
- Advisory/Warning signage no longer posted in OK and TX. General informational flyer posted throughout the recreation season
- Continued coordination with ODEQ, OTRD, TCEQ, KDHE

State Agency Collaboration – Ohio River Basin

- Division Guidance Memo dated 29-June-2012
  - District HAB Plans
    - World Health Organization (WHO) Guidelines
    - Promote internal and external communication
    - Consistency across districts sharing jurisdiction in a state

Ohio Basin Status

- OH, IN and KY
  - States have HAB response strategies
  - USACE *supports* the state agencies
    - Sample collection and analysis (state methods)
    - Sign posting (state signs and plan)
- WV and PA
  - State agencies in early stages of HAB plan development
  - Corps is still following WHO guidance and posting signs

NEW TECHNOLOGIES

Remote Sensing and GIS to Support Planning & Operations

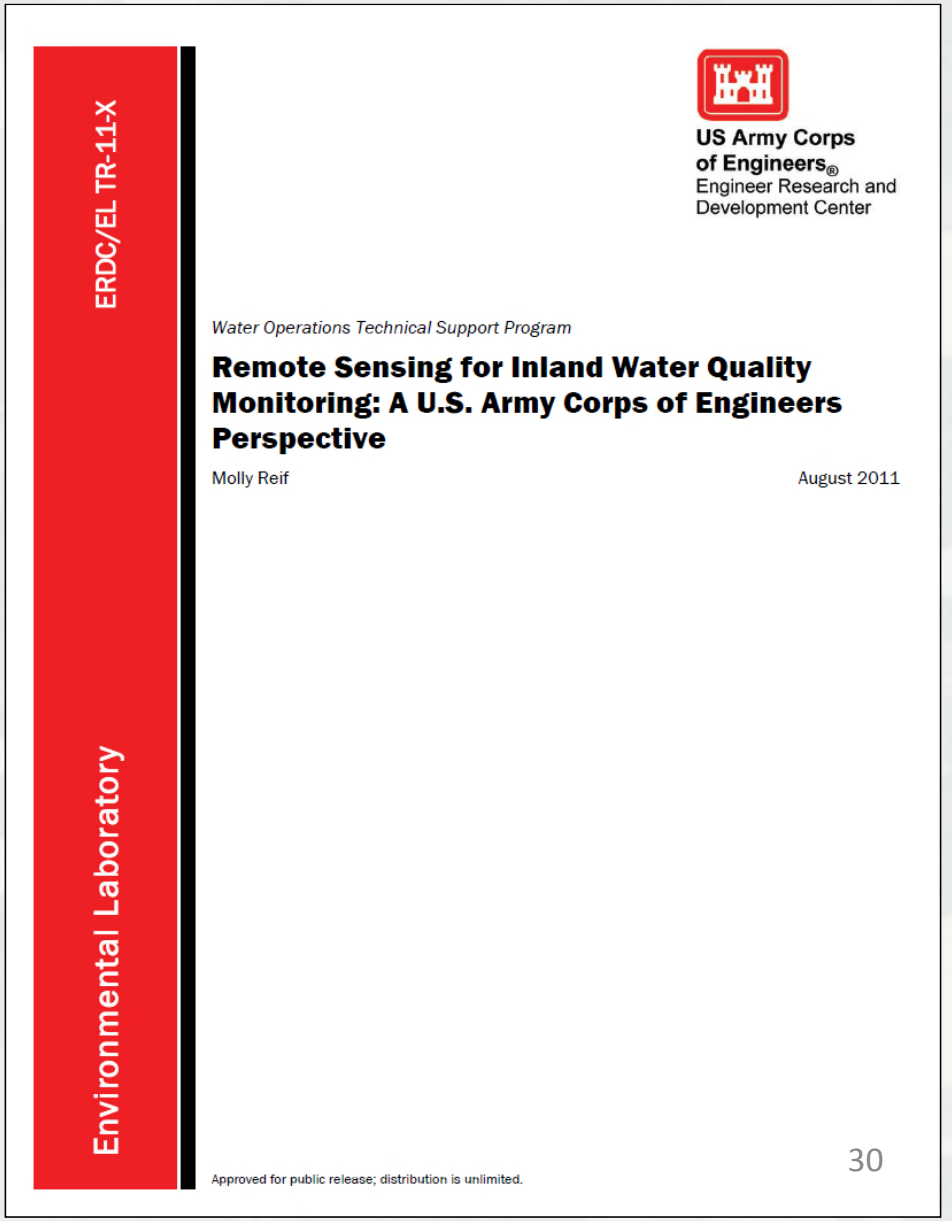
Molly Reif, Research Geographer, GISP
US Army Engineer Research and Development Center
Environmental Laboratory
Joint Airborne Lidar Bathymetry Technical Center of Expertise

October 8, 2015
Vicksburg, MS

Joint Airborne Lidar Bathymetry Technical Center of Expertise

Technical Report: *Remote Sensing for Inland Water Quality Monitoring: A U.S. Army Corps of Engineers Perspective*

- Evaluates RS as a tool for augmenting current water quality monitoring efforts.



Water Quality Monitoring: Harmful Algal Bloom Detection

Support the Great Lakes & Ohio River Division's water quality monitoring program

- ✓ Assess hyperspectral and other imagery to identify water quality indicators of Harmful Algal Blooms (i.e. toxic algae)
- ✓ Limited resources for monitoring hundreds of USACE lakes/reservoirs
- ✓ RS tools to help prioritize field-based monitoring and provide early warning system

Approach

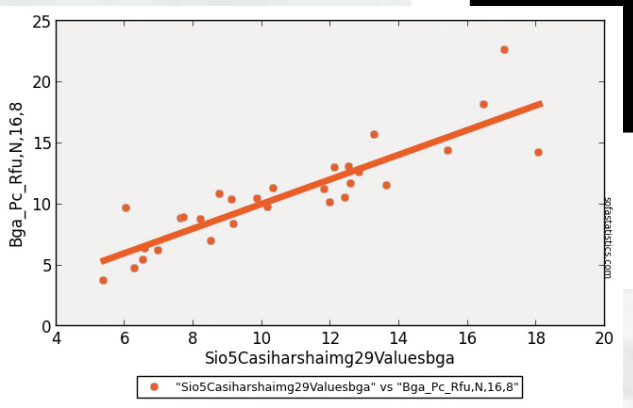
1. Coordinated CASI hyperspectral flights and field sampling:
   - Taylorsville Lake, KY: June 18 2014
   - Harsha (East Fork) Lake OH: June 27 2014
2. Work with the UC and NOAA to develop/refine algorithms to estimate HAB indicators such as chlorophyll (Bloom Index, Cyanobacterial Bloom Index, Maximum Chlorophyll Index, etc)

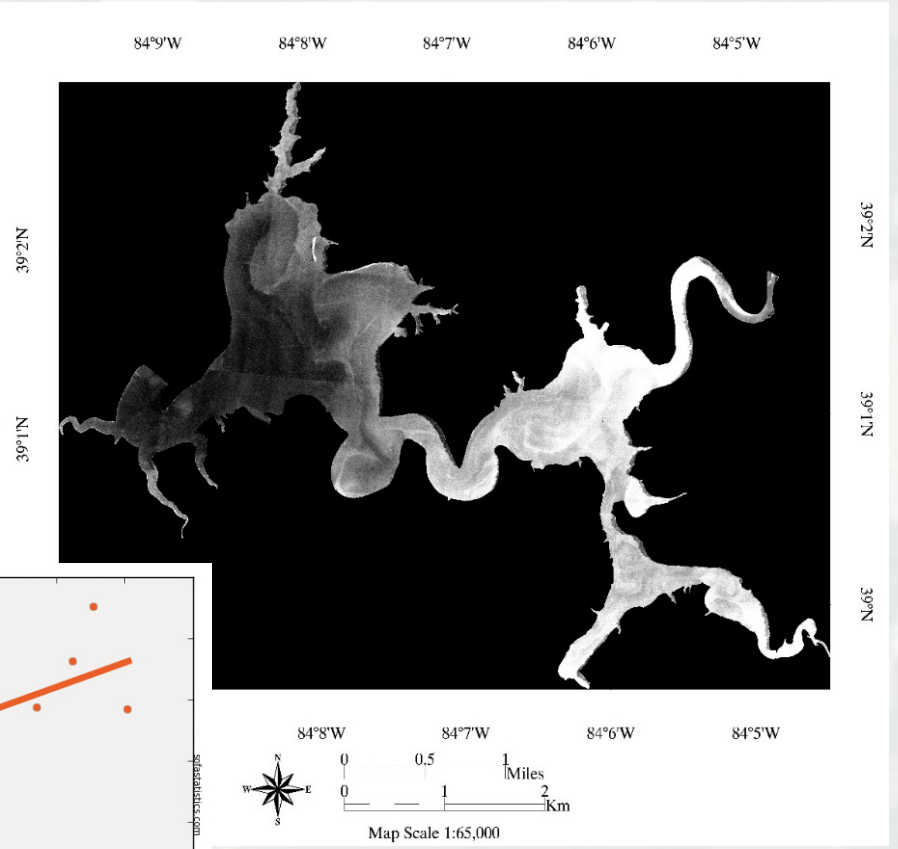
- Many partners for coordinated airborne and field surveys:

  Great Lakes & Ohio River Division, the Louisville District, the Huntington District, The University of Cincinnati, USEPA, the Kentucky Division of Water, the ERDC Environmental Laboratory, and JALBTCX

Coordinated Field Sampling:

1. Water samples for lab analysis by USEPA
2. ASD spectra to evaluate atmospheric correction of CASI imagery
3. In situ sensor measurements of Chl-a indicator, Phycocyanin indicator, Turbidity, Specific Conductance, pH, water temperature, and dissolved oxygen
4. Secchi Depth measurements
5. GPS location





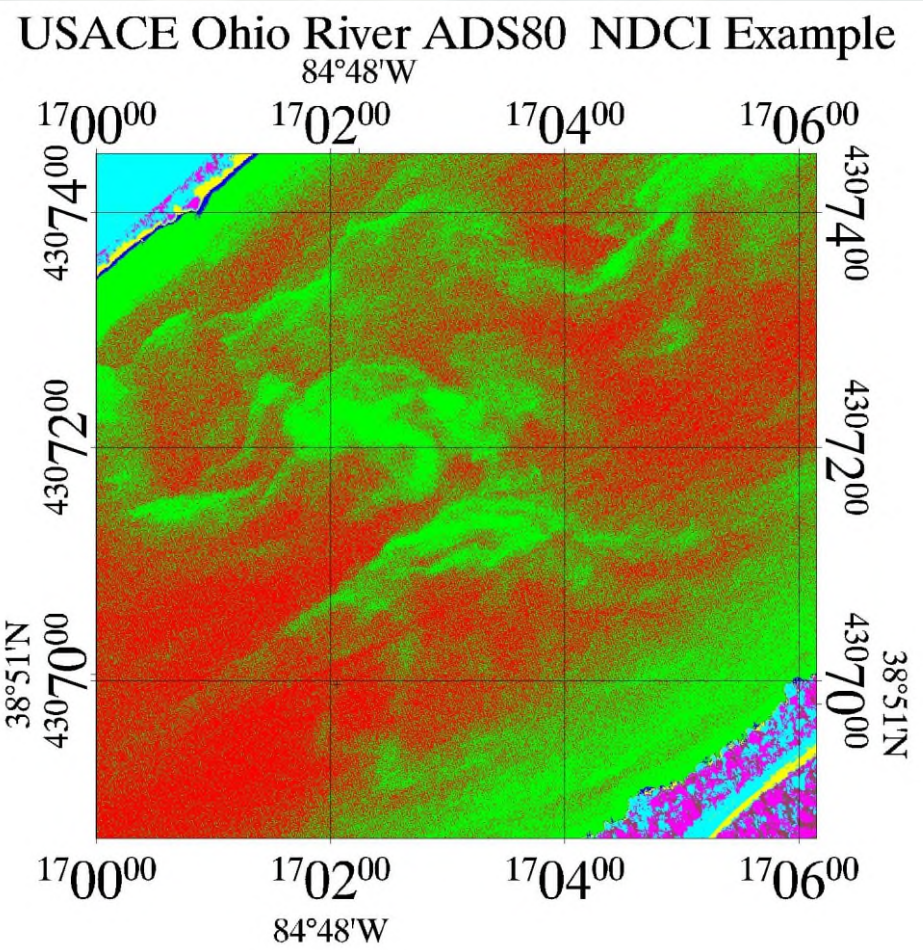
SI05 algorithm applied to CASI imagery with pixel brightness proportional to phycocyanin (proxy for cyanobacterial or blue-green algal biomass)

Most algorithms suited to CASI due to numerous, narrow bands well placed for : 1) shape metric algorithms for the Chl-a peak between 700 and 714nm and 2) determining the slope of the (aquatic) “red” or “veg” (vegetation) edge

Harmful Algal Bloom Monitoring in the Ohio River

LRD contacted EL on 9/11 to assist with bloom and improve situational awareness for the river districts and regional partners

- Airborne survey requested for ~700 miles of river using high-resolution 4-band sensor (ADS80)
- Survey occurred Sept 16-21 and imagery provided to LRD by Sept 23 to better focus and prioritize monitoring and response
- Healthy veg reflects NIR wavelengths appears red/pink in CIR imagery; algorithms such as NDCI used to exploit this



USACE RESEARCH

ERDC
Engineer Research and Development Center

Aquatic Plant Control Research Program

Reducing eutrophication and the prevalence of harmful algal blooms

Carina M. Jung
Jed O. Eberly
Heather M.K. Smith
Kurt Getsinger

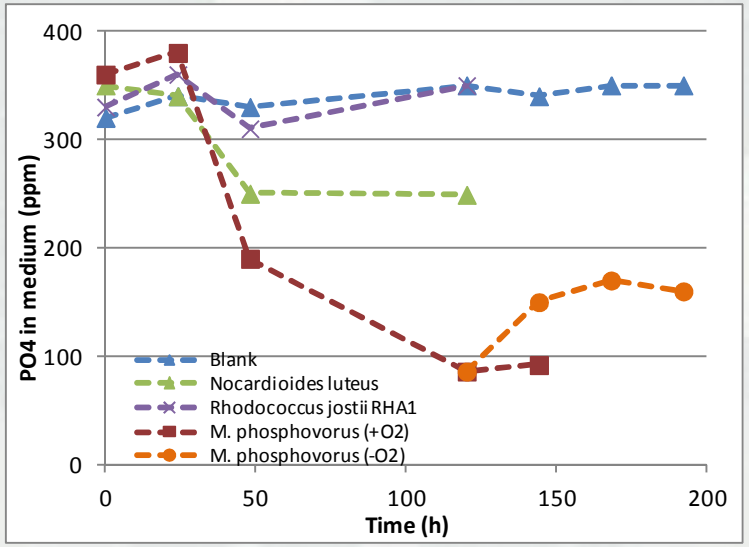
Environmental Lab

ERDC Vicksburg

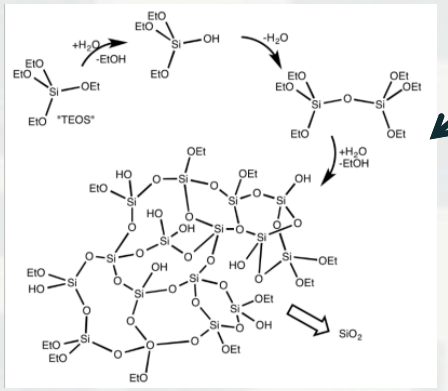
APCRP Funding FY15-19

OBJECTIVES

1) Test immobilization platforms for the introduction of phosphate accumulating bacteria into waterways as a biological means to remove excess P
2) Assess the efficiency of P removal from test waters and the regeneration of “clean” cells
3) Develop and test the efficacy of biological filters in influents as well as open water systems

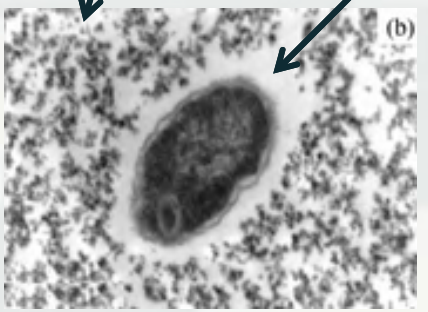


Aerobic (+O2) phosphate uptake by known accumulators. Shift to anaerobiosis (-O2) leads to phosphate release by *M. phosphovorous*, this study’s primary Phosphate Accumulating Organism (PAO).



Sol Gel Matrix

Bacterium



Benefits to the Corps and APCRP

- The USACE is uniquely positioned to take the lead in a novel method for reduction and removal of phosphorous from freshwater systems in an effort to curb HAB and hypoxia events.

- This technique has potential for very large scale up, low cost, high profile environmental stewardship as an ecologically friendly, non-invasive solution

- If successful, this technique could become patented and marketable, as well as providing a resource for commercially available phosphorous

Physicochemical Treatment of Cyanobacteria and Microcystin Toxin by Hydrodynamic Cavitation and Advanced Oxidation

Afrachanna Butler
Catherine Thomas
Christopher Griggs
Alan Katzenmeyer
Victor Medina

Environmental Lab

ERDC Vicksburg

APCRP Funding FY15-16

Hydrodynamic Cavitation Treatment

Purpose

- Develop a minimally invasive means of managing Harmful Algal Blooms (HABs)

Hypothesis

- Mimicking the treatment technology of the KRIA is hypothesized to be effective in cyanobacteria treatment due to its physical and chemical mode of action

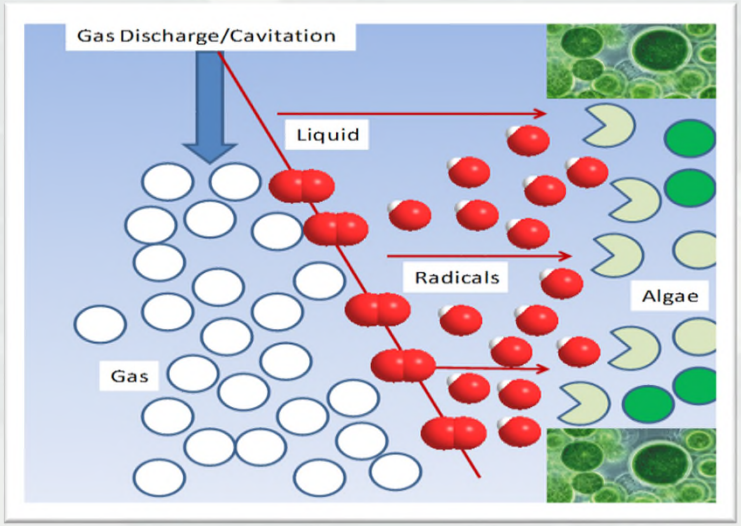
Rationale

- The mechanism of hydrodynamic cavitation alone physically destroys cyanobacteria while chemically oxidizing microcystin toxins as cavitation fields produce oxygen radicals

Research Objectives

1) Evaluate the effect of hydrodynamic cavitation to remove cyanobacteria and its associated toxins from water under various cavitation fields

2) Determine oxygen species generated from the varied cavitation fields



FY 16 Tasks

- Continue with cyanobacteria testing to determine the frequency of treatments needed to prevent algal blooms
- Conduct cavitation treatment with cyanobacteria from Lake Erie
- Determine oxygen radical species generated from each treatment nozzle (O_2^-/OH^- Assays and Electron Paramagnetic Resonance Analyses)

Photo Courtesy of Rose Reilly

Aphanizomenon flos-aquae bloom at Allegheny Reservoir